High-Q Piezoelectric Nanomechanical Filter Arrays

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Project Goals
- Functional filter banks based on nano-scale piezoelectric structures:
  - orders-of-magnitude size reduction compared to SAW devices
  - direct integration with VLSI (ZnO) and high-speed electronics (AlAs)
  - low power operation
- Piezoelectric coupling scales into the nano regime much more favorably than capacitive coupling for lower insertion loss, higher SNR
- High-Q single crystal piezoelectric materials, e.g. AlAs, will enable direct integration with high speed electronics, optoelectronics
- Comparison of displacement-based capacitive and strain-based piezoelectric doubly-clamped beam resonators up to 10GHz

Why piezoelectric filters?
- AlAs is an excellent material for nanoscale resonators
- Higher piezoelectric coupling than ZnO, AlN, GaAs
- Good fracture toughness, ultimate yield strength
- Moderate density and stiffness for higher frequencies than GaAs
- Single xtal epitaxial growth, lattice match to GaAs for high Q

AlAs Piezoelectric Filters

- AlAs micromachining used for device release
- Typical anisotropic etch profiles shown at right
- 3-layer heterostructures fabricated via MBE, FIB, and wet etching
- Plasma etching processes under development for selective AlGaAs/AlAs etching
- Initial micropost structures designed for d31, d33, Q, f s measurements
- Epitaxial regrowth for future devices
- Typical clamped-clamped beam AlAs heterostructure patterned by FIB:

AlGaAs/AlAs/AlGaAs resonator fabrication

- Typical PZT-based microscale filter and spectrum output:
- Related designs in progress:
  - bending mode resonators (use d31, with higher modes, new anchor designs)
  - shear mode block resonators (use high d31)
  - thickness mode disk resonators (use d33, but higher Q expected)